variation in micro-satellite DNA for the purposes of differentiating populations (i.e., identifying genetic structure; Paetkau et al. 1995, p. 347; Paetkau et al. 1999, p. 1,571; Cronin et al. 2006, p. 655). Additionally, genetic analyses for the purpose of identifying population bottlenecks require accurate quantification of mutation rates to determine how far back in time an event can be detected and a combination of mitochondrial and nuclear DNA analyses to eliminate potential alternative factors, other than a population bottleneck, that might result in or counteract low genetic variation (Driscoll et al. 2002, pp. 420–421; Hedrick 1996, p. 898; Nystrom et al. 2006, p. 84). The results of micro-satellite studies for polar bears have documented that within-population genetic variation is similar to black and grizzly bears (Amstrup 2003, p. 590), but that among populations, genetic structuring or diversity is low (Paetkau et al. 1995, p. 347; Cronin et al. 2006, pp. 658–659). The latter has been attributed with extensive population mixing associated with large home ranges and movement patterns, as well as the more recent divergence of polar bears in comparison to grizzly and black bears (Talbot and Shields 1996a, p. 490; Talbot and Shields 1996b, p. 574; Paetkau et al. 1999, p. 1,580). Inferring whether the degree of genetic variation from these studies is indicative of a population bottleneck, however, requires additional analyses that have yet to be conducted. Furthermore, the very limited fossil record of polar bears sheds little light on possible population-level responses of polar bears to previous warming events (Derocher et al. 2004, p. 163).

Thus, while polar bears as a species have survived at least one period of regional warming greater than present day, it is important to recognize that the degree that they were impacted is not known and there are differences between the circumstances surrounding historical periods of climate change and present day. First, the IPCC concludes that the current rate of global climate change is much more rapid and very unusual in the context of past changes (Jansen et al. 2007, p. 465). Although large variation in regional climate has been documented in the past 200,000 years, there is no evidence that mean global temperature increased at a faster rate than present warming (Jansen et al. 2007, p. 465), nor is there evidence that these changes occurred at the same time across regions. Furthermore, projected rates of future global change are much greater than rates of global temperature increase during the past 50 million years (Jansen et al. 2007, p. 465). Derocher et al. (2004, p. 163, 172) suggest that this rate of change will limit the ability of polar bears to respond and survive in large numbers. Secondly, polar bears today experience multiple stressors that were not present during historical warming periods. As explained further under Factors B, C, and E, polar bears today contend with harvest, contaminants, oil and gas development, and additional interactions with humans (Derocher et al. 2004, p. 172) that they did not experience in previous warming periods, whereas during the HTM, humans had just begun to colonize North America. Thus, both the cumulative effects of multiple stressors and the rapid rate of climate change today create a unique and unprecedented challenge for present-day polar bears in comparison to historical warming events.

Effects of Sea Ice Habitat Change on Polar Bears

Observed and predicted changes in sea ice cover, characteristics, and timing have profound effects on polar bears (Derocher and Stirling 1996, p. 1,250; Stirling et al. 1999, p. 294; Stirling and Parkinson 2006, p. 261; Regehr et al. 2007b, p. 18). As noted above, sea ice is a highly dynamic habitat with different types, forms, stages, and distributions that all operate as a complex matrix in determining biological productivity and use by marine organisms, including polar bears and their primary prey base, ice seal species. Polar bear use of sea ice is not uniform. Their preferred habitat is the annual ice located over the continental shelf and inter-island archipelagos that circle the Arctic basin. Ice seal species demonstrate a similar preference for these ice habitats.

In the Arctic, Hudson Bay, Canada has experienced some of the earliest ice changes due to its southerly location on a divide between a warming and a cooling region (Arctic Monitoring Assessment Program (AMAP) 2003, p. 22), making it an ideal area to study the impacts of climate change. In addition, Hudson Bay has the most extensive long-term data on the ecology of polar bears and is the location where the first evidence of major and ongoing impacts to polar bears from sea ice changes has been documented. Many researchers over the past 40 years have predicted an array of impacts to polar bears from climatic change that include adverse effects on denning, food chain disruption, and prey availability (Budyko 1966, p. 20; Lentfer 1972, p. 169; Tynan and DeMaster 1997, p. 315; Stirling and Derocher 1993, pp. 241–244). Stirling and Derocher (1993, p. 240) first noted changes, such as declining body condition, lowered reproductive rates, and reduced cub survival, in polar bears in western Hudson Bay; they attributed these changes to a changing ice environment. Subsequently, Stirling et al. (1999, p. 303) established a statistically significant link between climate change in western Hudson Bay, reduced ice presence, and observed declines in polar bear physical and reproductive parameters, including body condition (weight) and natality. More recently Stirling and Parkinson (2006, p. 266) established a statistically significant decline in weights of lone and suspected pregnant adult female polar bears in western Hudson Bay between 1988 and 2004. Reduced body weights of adult females during fall have been correlated with subsequent declines in cub survival (Atkinson and Ramsay 1995, p. 559; Derocher and Stirling 1996, p. 1,250; Derocher and Wiig 2002, p. 347).

Increased Polar Bear Movements

The best scientific data available suggest that polar bears are inefficient moving on land and expend approximately twice the average energy than other mammals when walking (Best 1982, p. 63; Hurst 1982, p. 273). However, further research is needed to better understand the energy dynamics of this highly mobile species. Studies have shown that, although sea ice circulation in the Arctic is clockwise, polar bears tend to walk against this movement to maintain a position near preferred habitat within large geographical home ranges (Mauritzen et al. 2003a, p. 111). Currently, ice thickness is diminishing (Rothrock et al. 2003, p. 3649; Yu et al. 2004) and movement of sea ice out of the polar region has occurred (Lindsay and Zhang 2005). As the climate warms, and less multi-year ice is present, we expect to see a decrease in the export of multi-year ice (e.g., Holland et al. 2006, pp. 1–5). Increased rate and extent of ice movements will, in turn, require additional efforts and energy expenditure by polar bears to maintain their position near preferred habitats (Derocher et al. 2004, p. 167). This may be an especially important consideration for females encumbered with small cubs. Ferguson et al. (2001, p. 51) found that polar bears inhabiting areas of highly dynamic ice had much larger activity areas and movement rates compared to those bears inhabiting more stable, persistent ice habitat.